FORT LEWIS, YAKIMA FIRING CENTER, AND VANCOUVER BARRACKS/CAMP BONNEVILLE BASEWIDE ENERGY USE PLAN

EXECUTIVE SUMMARY

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1.0 INTRODUCTION

This Executive Summary presents an overview of a series of studies, mostly energy-related, of Fort Lewis, Yakima Firing Center, Vancouver Barracks, and Camp Bonneville. Collectively, the work is known as the Basewide Energy Use Plan and is a part of the Energy Conservation Investment Program (ECIP). The original contract was advertised in February 1978 and the contract executed in September 1978. There have been ten additions to scope and fee, the latest in September 1983. Major components of the work are listed in Figure 1-1 and described below.

Basewide Energy Use Plan

This basic study examined energy conservation potential in about 4000 buildings using 62 sample buildings as representative of most buildings on the four installations. The process capitalized on the fact that buildings on Army installations tend to be repetitive in design, with many structures built to the same general plan. Therefore, the buildings on each post were grouped by design and function and a sample was chosen to represent each group. At one extreme, a sample building was a unique, major building, representing no others. At the other extreme, one half-duplex represented 1298 half-duplexes and single-unit family houses.

Each of the 62 samples was analyzed with the Building Loads Analysis and System Thermodynamics (BLAST) computer program. Plans were reviewed and detailed inspections made of each sample building to establish existing conditions and identify potential energy conservation measures. BLAST analyses were then used to evaluate the effectiveness of the conservation measures affecting building envelope and heating and cooling systems. Other methods were used as appropriate to evaluate effectiveness of conservation measures not suited to BLAST analysis. Examples include automatic flue dampers and electric ignition on gas-fired boilers and water heaters. Implementation costs and incremental maintenance and operation costs were estimated for each conservation measure and discounted benefit-cost ratios were calculated. These results for the 62 sample buildings were then applied to all the buildings to extend the results to basewide conservation estimates.

From these data, Directorate of Facilities Engineering, Fort Lewis, (DFAE) determined which conservation measures were to be proposed for implementation. First pages of DD Forms 1391 were prepared for those conservation measures chosen by DFAE.

In addition to building envelopes and systems, a number of specific energy conservation measures and alternative energy sources were examined, including maintenance and operation measures. Examples include replacement of lights with more efficient fixtures, disconnecting excess lighting fixtures, replacement of fluorescent lamps with lower wattage lamps, and removal of two lamps and disconnection of one ballast from four-lamp fluorescent fixtures. Solar and wind energy and solid waste and wood waste fuels were considered; use of the waste fuels was recommended.

Increment G for Yakima Firing Center and Vancouver Barracks

A reexamination of two subposts to Fort Lewis was performed to identify any additional energy conservation measures with discounted benefit-cost ratios greater than 1.0. The examination emphasized maintenance and operation measures and minor construction measures. Fort Lewis itself was not included because the work would have duplicated previous efforts of DFAE.

Energy Monitoring and Control System

Building upon data and analyses gathered in the Basewide Energy Use Plan basic study, potential for an energy monitoring and control system for Fort Lewis, Yakima Firing Center, and Vancouver Barracks, was examined. Results indicate that EMCS may be viable at Yakima Firing Center and in selected areas of Fort Lewis.

Biomass Energy Plant Concept Study

Potential costs and benefits of a large, wood-fired cogeneration plant serving Fort Lewis and McChord AFB were estimated in a separate increment of the study. The fuel source was to be forest residues from Fort Lewis timber operations and from timber operations of state and federal forest lands in the vicinity. Most permanent buildings except family housing on the two posts were considered. The concept plant was estimated to provide 15,000 kW of firm electric power and save nearly 8 million gallons of oil (including some natural gas at its energy equivalent of oil) per year. The economic viability of wood waste fuel depends on the power purchase rates of the local utility and the willingness of the U.S. Forest Service to establish long-term contracts for sale of forest residues. Neither issue could be established at the time of the study, and both have been continually in flux since then.

Increment E (Solid Fuel Central Plant Study)

Solid fuel central heating plants were examined as replacements for existing oil-fired central plants and oil- and gas-fired individual heating plants at Fort Lewis. Fuels considered were coal, wood waste from Fort Lewis timber operations, and solid waste from Fort Lewis and adjacent McChord Air Force Base. In a five-plant concept, four were projected to have benefit-cost ratios greater than 1.0. A single-plant concept with service area identical to the five-plant concept was projected to have benefit-cost ratio of 1.3. Major capital costs included the new plants, substantial expansion of steam and hot water distribution systems, and conversion of many buildings from individual to central heating systems.

Radiant Heating Schemes, Building 9570 and 9580, Fort Lewis

Natural gas and electric radiant heat were examined for use in two large industrial buildings at Fort Lewis. Both radiant supplements to existing steam heating and full radiant replacement of existing steam heating were analyzed. The gas-fired radiant supplement was estimated to be the most cost-effective. The electric radiant replacement system was least cost-effective.

Supplement to the Utility Analysis, Sanitary Sewage and Disposal System

Trunk lines and major laterals of the Fort Lewis sanitary sewers were tested and observed to determine their physical condition. Smoke tests were used to find storm drains and building downspouts connected to sanitary sewers and to find open sewer stubs. Piezometer measurements were used to test for submerging of mains (below groundwater level). Liquid level monitoring stations were established to investigate liquid level and flow. The study indicated substantial amounts of summer exfiltration and winter infiltration from and to the sewers.

Supplement to the Utility Analysis, Heating, Natural Gas, and Electrical Distribution Systems; Street Lighting Systems

Surveys of energy distribution systems and street lighting were made and utility map overlays revised to show the existing systems. Written summaries of energy distribution utility conditions were made and a summary paper on military base exterior lighting criteria was prepared.

Reservation Map, Camp Bonneville

A new base map and overlays of physical features and improvements were made, beginning with taking of new aerial photos and analysis with photogrammetric methods.

It is important to recognize that this project was contracted as a Basewide Energy Use Plan on a very early version of the scope of work that later became the Energy Engineering Analysis (EEA) standard scope. While some of the late components of work were adapted from EEA increments, the earlier scopes were substantially different. Readers of this document who are familiar with EEA should expect to find differences.

It is also important to recognize that economic analysis rules and procedures differ from present practice as well. Analysis procedures generally follow original ECIP guidance, DTL 1110-34-8, 25 January 1978. A few analyses in the Energy Monitoring and Control System study were redone in accordance with the guidance of ETL 1110-3-332, 22 March 1982, and subsequent ECIP guidance. Moreover, energy rates and technology have changed dramatically over the five years of the study, and many early results are no longer valid.

The analyses reported herein and in the documents being summarized are based on current interpretations of codes, standards, and other information and processes available to the design professions and on assumption and limitations inherent in the scope of work. All information herein has been prepared in accordance with generally accepted engineering practice.

FIGURE 1-1

MAJOR REPORTS, BASEWIDE ENERGY USE PLAN SERIES

REPORT	LAST SUBMITTAL
• Supplement to the Utility Analysis Sanitary Sewer and Disposal System	Final, December 1979
• Basewide Energy Use Plan Technical Report Technical Appendices	Final, October 1980
• Biomass Energy Plant Concept Study	Final, September 1980
• Solid Fuel Central Plant Concept Study (Increment E)	Final, November 1981
• Increment G Yakima Firing Center Vancouver Barracks	Final, March 1982
• Radiant Heating Schemes, Buildings 9570 and 9580	Final, March 1982
• Energy Monitoring and Control System	Final, October 1983

2.0 RESULTS, CONCLUSIONS

Results of the several studies are best treated by grouping results of similar studies as follows:

A. Energy conservation actions in buildings and small central heating plants. The basic study, the Increment G study, the Radiant Heating Schemes study and the Energy Monitoring and Control Systems study are part of this group.

B. Alternate fuels and configurations of central heating plants. The Biomass Energy Plant Concept Study and the Solid Fuel Central Plant Study (Increment E) are part of this group. Some analyses in the Section 12.3, Consolidation and Renewable Fuels part of the basic study also contribute to this topic.

C. Renewable Resources

D. Nonenergy and Miscellaneous. The utility analysis supplements and the mapping comprise this group.

2.1 Energy Conservation in Buildings

The largest element of this work was the survey and detailed energy analysis of 62 buildings at Fort Lewis and its subinstallations as described in Section 3. The results of the analyses were a large set of conservation opportunities with characteristics quantified in terms of Energy-Cost factor (E/C) and Benefit-Cost ratio (B/C). Applying these results, by similarity, to the 4000-odd buildings and then ranking in priority order, a draft conservation program resulted. Following review with DFAE, the lists were culled to eliminate conservation improvements implemented after the 1975 study base time or in progress at the time of the study. Items for buildings scheduled for demolition or major renovation were deleted. Small, inexpensive items were removed as better suited to be done by Post staff as maintenance measures. The rest were developed into the front pages of a series of seven Forms 1391. These are listed in Figure 2-1.

A resurvey of Vancouver Barracks and Yakima Firing Center was made as Increment G, with emphasis on maintenance and operation actions for energy conservation. Results are summarized in Figure 2-2. All items listed have discounted benefit-cost ratios greater than 1.0.

Few cost-effective improvements to lighting were identified, primarily because of the low electric rates. Higher rates and technology improvements have occurred since that time and new analysis of potential lighting energy conservation is warranted. At Yakima, for example, we found we could substitute 175W high pressure sodium lamps for existing 400W mercury vapor lamps in floodlights but substituting 175W HPS for 250W MV street lights was not cost-effective. At that time 175W was the smallest HPS available. Now HPS lamps are available down to 35W sizes and electric rates have increased. Pacific Power and Light rates at Yakima Firing Center went from 1.06 cents per kwh in the 20 Jan 78 rate increase to 1.861 cents/kwh in the 1 Jan 81 rate increase, both for energy in the tail block. With lighting technology improving and electric rates increasing rapidly, many things are cost-effective now which were not in 1979-1980.

A special study was performed to examine use of radiant heating as a supplement and as an alternate to the conventional heating systems in two large Fort Lewis industrial facilities, Building Numbers 9570 and 9580. Use of gas radiant heating as a supplement saves the most energy and is most cost-effective, as shown in Figure 2-3. The energy savings values for the two electric alternatives are misleading because of the use of 11,600 Btu/Kwh source energy value for new radiant energy used. Economics were still positive, however, because electricity from Tacoma City Light was less than $3.00 per MBtu, including demand, based on 3413 Btu/Kwh.[1] The all-electric system exceeded the capacity of primary distribution in the area and cost of an additional 13 KV transmission line drove benefit-cost ratio down to 0.77.

2.2 Central Plants

Several alternatives for central plants were examined as part of the basic energy plan and as special studies. The thrust was toward larger plants serving greater proportions of the cantonment and using solid fuels, preferably renewable fuels.

At the extreme, we looked at a single, large cogeneration plant, fired with wood logging residues and serving steam to most of the adjacent McChord AFB cantonment as well as the Fort Lewis cantonment. The initial concept was use of wood residues from Fort Lewis silviculture operations, but that source proved to be insufficient and off-post sources were investigated.

The information on cost and quantity of on-Post wood fuel was used to evaluate another configuration, one in which two smaller plants were to be fired with solid waste for base load and with wood for peaking. The solid waste stream was the 80-odd tons collected every weekday from Fort Lewis and McChord AFB. The intent was to use up all of the solid waste every week in such a way that (a) it was not necessary to store it for more than a weekend and (b) the plants and steam distribution systems were extensive enough to use all of the heat. To accomplish the latter, an auxiliary fuel was needed for the extra loads in the heating

1 From 1 January 1979 to 8 July 1981, the Tacoma City Light charges were 4.9 mills/Kwh energy (yes, mills, not cents) and $1.50 per kw of demand. Effective 8 July 1981, the rates were 6.7 mills/Kwh and $2.41/Kw of demand. Few electrical conservation measures were cost-effective.

season, and the wood fuels from the Post were chosen. The wood is harvested in winter, is cheap, and works well either separately or mixed with solid waste.

An alternative use of solid waste, firing a single plant and discarding the excess heat in warm weather, was analyzed by Civil Engineering Research Laboratory, Corps of Engineers. After DFAE chose the CERL proposal for solid waste fuel and decided against the use of wood, one waste-plus-wood concept was revised to a coal concept and front pages of a Form 1391 prepared. A second plant concept for coal fuel was concurrently advanced in priority to serve the needs of the new Madigan Army Medical Center now in design.

The resulting configuration of central plants is shown in Figure 2-4. Plant "A" at upper right is to be a new coal-fired plant serving Logistics Center, new MAMC and the existing Madigan buildings with new uses. The CERL concept of solid waste fuel in a converted plant is at center. To the left is existing Plant No. 14 converted to coal fuel and with distribution system extended to cover most of the western portion of the cantonment. Forms 1391 have been submitted for the first two by HQ, I Corps and Fort Lewis, and first pages of a Form 1391 have been prepared for the Plant No. 14 conversion. Information available to the author is summarized in Figure 2-5.

2.3 Renewable Energy Sources

A wide variety of sources of energy are both renewable and underused. Some, such as hydroelectric energy, are used and are important regionally. Others, such as wood, have been important in the past and are regaining attention as prices of conventional energy sources climb. Others, such as wave energy, lack the technology for immediate exploitation but are the subject of current research.

Figure 2-6 summarizes the potential for renewable energy resources at all four installations. The sources listed fall into three categories:

- Those sources available or probably available in the near term, including wood fuel at Fort Lewis and Camp Bonneville, solid waste fuel at Fort Lewis, Yakima Firing Center and Vancouver Barracks, and geothermal energy at Yakima. It is recommended that wood and solid waste use be initiated at Fort Lewis and that wood use be continued at Camp Bonneville. Early investigation of geothermal sources near the cantonment at Yakima is also recommended.

- Those sources which will probably become economically and technically feasible in the 1985-1990 period, including methane from fermentation of organic feedstocks, solar energy, and wind energy.

- Those sources not expected to be significant on or near the four installations, including tide and wave power and new hydroelectricity.

2.4 Other Work Items

As described in the Introduction, several utility analysis supplements were prepared and utility maps were updated. One investigation was of trunk sewer condition and indicated that two trunk sewers and their major laterals needed rehabilitation at the time of the report, 1979. Review of steam and hot water distribution systems confirmed the opinion of DFAE that most of the systems needed rehabilitation. DFAE had acted to accomplish that and some of the work has been done.

A survey was made to determine the laws, regulations, and ordinances of Federal, State and local governments which will restrict or influence planning for and development of Fort Lewis and its subinstallations. These are listed, together with a brief explanation of content, in Chapter 5.0.

FIGURE 2-1
FORMS 1391 DEVELOPED
Building Energy Conservation
Basewide Energy Use Plan

Project No.	Number of Bldgs.	Improvement	Cost, FY 84 10^3 Dollars	Discounted Benefit/Cost	Energy Saved 10^3 MBtu/yr	Simple Payback, Yr
T-564	2201	Weatherstrip family housing; Fort Lewis	$ 3,109	9.0	129	2.2
T-565	149	Lighting modifications, weatherstripping, heating controls; Fort Lewis barracks, shops, and admin.	$ 1,408	19.6	152	0.9
T-566	342	Weatherstrip, insulate, heating controls; North Fort Lewis	$ 4,744	11.0	261	1.6
T-567	120	Weatherstrip, insulate, heating controls; main post temporaries in use, Fort Lewis	$ 2,631	10.6	140	1.7
T-568	212	Weatherstrip, insulate heating controls, automatic flue dampers and electric ignition; main post permanent buildings, Fort Lewis	$ 4,838	15.7	447	1.1
T-569	90	Weatherstrip, insulation, and miscellaneous; Yakima Firing Center	$ 990	10.1	55	1.8
T-570	36	Weatherstrip, insulation, heating controls, automatic flue dampers and electric ignition; Vancouver Barracks	$ 574	10.1	36	1.8

FIGURE 2-2
INCREMENT G RECOMMENDATIONS

Number of Buildings	Improvement	Cost, FY 82 Dollars	Energy Saved MBtu/Yr	Simple Payback, Years
Yakima Firing Center				
20	Insulate hot water tanks, lines; reduce temperature	1,940	2342	0.3
8	Replace light fixtures	$13,997	520	13.6
4	Window film	2,889	75	6.7
5	Replace boilers	$203,163	8409	2.5
Vancouver Barracks				
30	Insulate hot water tanks, lines; reduce temperature	1,510	1180	0.3
25	Replace boilers	164,577	8253	3.6

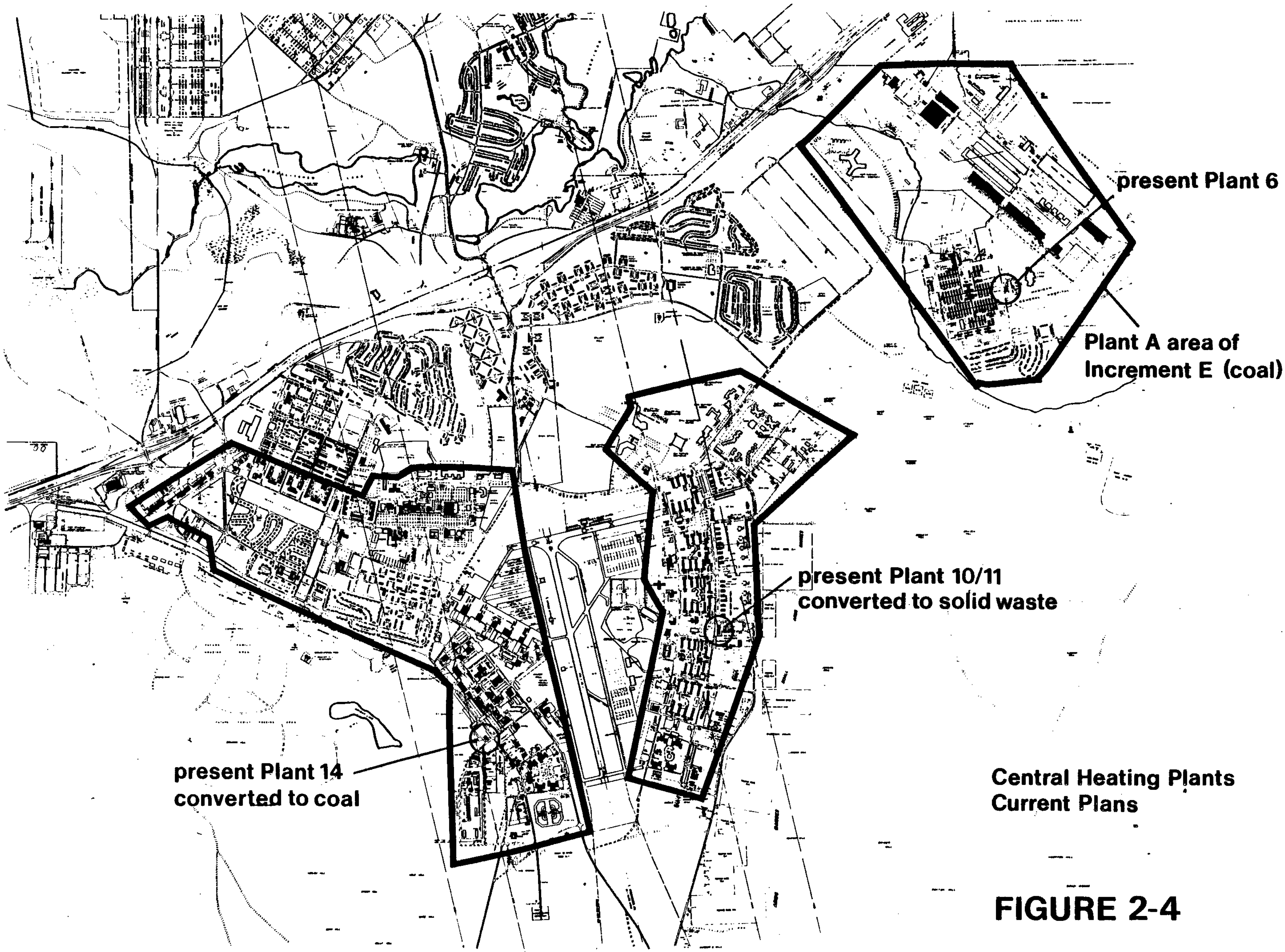
FIGURE 2-3
Radiant Heating Schemes, Buildings 9570 and 9580
Cost-Benefit Summary

Alternative	Capital Cost Dollars[1]	Maintenance Costs/ Dollars/Yr[2]	Energy Cost Reduction Dollars/Yr[2]	Energy Saved MBtu/Yr[3]	Discounted Benefit Cost	Payback Period Years
Replace heating with gas infrared units	767,803	58,995	145,261	18,879	1.71	6.85
Replace heating with electric infrared unit	2,497,665	81,282	196,668	<67,980>	0.77	16.4
Spot or area heating with gas infrared units	414,231	29,498	199,332	28,364	5.87	2.3
Spot or area heating with electric infrared units	655,158	47,589	211,201	7,182	3.69	3.78

[1] At Midpoint of Construction, 1984

[2] At Beneficial Occupancy Date, 1985

[3] Source Energy Value of 11,600 Btu per kwh for electricity.



Central Heating Plants
Current Plans

FIGURE 2-4

FIGURE 2-5

PROJECTED CENTRAL HEATING PLANTS

Service Area	Fuel	Design Capacity	Cost, Year ($ Thousands)	Remarks
New Madigan AMC, old Madigan buildings, Logistics Center	Coal	154 MBtu/Hr	22,640 CWE, 1985	Concept by John Graham Company, Form 1391 by DFAE, Ft. Lewis
East side of Gray AAF	Solid Waste	NA	NA	Concept by Civil Engineering Research Laboratory
West side, main cantonment	Coal	107 MBtu/Hr	21,129 CWE, 1986	Conversion of Existing Plant No. 14. Concept by John Graham Company

NA - Not Available

FIGURE 2-6
POTENTIAL FOR RENEWABLE ENERGY
FORT LEWIS AND SUBINSTALLATIONS

Energy Source	Principal Energy Form	Media, Conditions	Year Available[1]	Compatible Use	Installation	Annual Production (Higher Heat Value)
Biomass – Wood	Boiler fuel	Steam to 1000°F, 1500 psi, hot water to 650°F	1980	Large boilers	Fort Lewis,[2] Camp Bonneville	380,000 MBtu
Biomass – Methane	Low Btu gas[3]	To 1000 Btu/scf	1985	Boiler fuel, stationary IC engines	Fort Lewis	Not known
Solar – Passive	Heat/building space	Air to 100°F	1980	Space heat, smaller buildings	All[4]	1.3×10^5 Btu/ft^2
Solar – Active	Warm air, water	Air to 120°F Water to 140°F	1985	Space heat, domestic hot water	Fort Lewis, Yakima FC	10^5 Btu/ft^2
Wind	Electricity	Not applicable	1985	Complement to hydro-electric utility	Yakima FC	5000 to 15,000 NWL per machine
Geothermal	Warm water	Water to 180°F[5]	1980	Space heat, domestic hot water	Yakima FC	Not applicable
Tides and Waves	Electricity	Not applicable			None	
Hydroelectric Power	Electricity	Not applicable			None	
Solid Waste	Boiler fuel	Steam, hot water to 700°F, 800 psi	1980	Large boilers	All except Camp Bonneville	300,000 MBtu at Fort Lewis

1 Year Available – approximate time that the technology reaches production status and is economic.
2 Open market fuel may be available at Yakima and Vancouver; on-Post cordwood is now used at Camp Bonneville.
3 If cleaned of noncombustible gasses, the fuel is a direct substitute for natural gas.
4 New construction only; retrofit not yet cost effective.
5 Heat pumping from water at 70° to 85°F.

3.0 ENERGY IN BUILDINGS; BASEWIDE ENERGY USE PLAN AND SUPPLEMENTARY STUDIES

The basic task of this large project was to identify and evaluate energy conservation measures in 4000-odd buildings at Fort Lewis and 140 buildings on the three subinstallations. The prescribed process was a physical survey of each building, examination of any available plans and specifications for each, simulation of energy flows in each building and potential modifications to it with a digital computer, and economic analysis of the potential modifications. Cost to perform this full process on every building was prohibitive, and a sampling system was substituted.

3.1 The Folder/Sample System

The sampling system was workable because Fort Lewis, like most large Army posts, has large numbers of buildings built to a few common designs and many others with very similar designs. Using the Building Information Schedules, buildings were sorted into groups of similar construction, age and use. Buildings without significant energy use for lighting or space conditioning (e.g., a storage shed or a 240 square-foot fuel dispensing building) were deleted. Results were reviewed with DFAE and a sample building was chosen to represent each group.

A total of 62 sample buildings were chosen, 44 for Fort Lewis, 10 for Yakima Firing Center, and 8 for Vancouver Barracks and Camp Bonneville together. Available plans from Fort Lewis files were copied and reviewed. Each sample building was examined by a team of architect, mechanical engineer, and electrical engineer. Plans, sketches, notes and other data were collected in "folders" numbered 1 through 44 for Fort Lewis, Y-1 through Y-10 for Yakima Firing Center, and V-1 through V-8 for Vancouver Barracks/Camp Bonneville. These folders and folder numbers were the basic record-keeping tool throughout the project.

Figures 3-1 through 3-7 illustrate the initial configuration of the system. Figure 3-1 identifies the 1299 family houses and half-duplexes represented in Folder 6, Sample Building No. 5410. The first entry is:

6-5410   2650-59   10   1588   2073

The 6-5410, of course, is the folder number and sample number. There are ten such houses in the 2600 Block, numbered 2650 through 2659. The sample, No. 5410, has a floor area of 1588 square feet. The average floor area of the ten in the block is 2073 square feet.

Each one of the 1299 units of Folder 6 is entered on a sheet like the one in Figure 3-2. This form shows that four units, Numbers 9816, 9817, 9824 and 9825 are NCO family housing built in 1963. They have concrete foundations, wood frame walls, and composition roofs. They are one-story, 4-bedroom units with 1691 square feet of floor area. They have individual oil-fired heat. Much the same information is shown in Figure 3-3, in which the same four units appear as part of the last entry. We do learn that they are in the area of Madigan AMC, hence are likely occupied by people assigned to Madigan. In Figure 3-1, they are part of the last entry.

Figures 3-4 through 3-6 show the architect's field notes on Building 5410, the sample. The information is in the detail required to model the thermal characteristics of the building. Lighting details are also noted, the usual practice on simple buildings. In the more complex buildings the electrical engineer conducted a separate lighting survey. Figure 3-7 presents the mechanical engineer's field notes. The initial contents of each folder also include one or more photographs of the sample and any drawings.

3.2 Computer Modeling and Manual Analysis

Much of the technical analysis was done by computer simulation using the Building Loads And System Thermo-dynamics (BLAST) digital computer model. This particular model calculates energy flows into and out of the building, by HVAC zone, hour-by-hour through a typical year. By calculating a present, or baseline, annual heating and cooling load and then recalculating the loads with some modification, the effect of the modification on annual energy use can be predicted. Common internal gains of heat, such as heat from people and lights, are taken into account. So-called "process" energy, from workplace machines and activities, was not considered in this project. BLAST input information and decisions form part of the Folder data.

Some potential improvements are not suited to BLAST analysis; automatic flue dampers is an example. These were analyzed manually, and the worksheets added to the appropriate Folders.

Figure 3-8 and 3-9 show sample results for Folder 6, Sample No. 5410. Some major energy characteristics are listed - "U" values, for example - along with analysis results for the existing building in Figure 3-8. Presentation of analysis results of conservation improvements are illustrated in Figure 3-9. Economic analysis was done by the methods of DTL 1110-34-8, 25 January 1978, which was in effect at the time the work was done. Results under the current instructions, ETL 1110-3-332, 22 March 1982, and subsequent directives, would be different. Energy costs used are discussed in Section 3.4

Figures 3-8 and 3-9 use the terms "Building Boundary Value" and "Post Boundary Value" in referring to energy consumption. For Folder 6 these are essentially the same, in that the oil fuel has the same value in the household furnace as it has as it enters the Post. Electricity is subject to small line and transformation losses which we assumed to be zero. Other buildings, however, are connected to central heating plants, and savings of oil at the post boundary are greater than savings of steam at the building boundary because of boiler losses. For example, if insulating in a building connected to a central plant saves 800 MBtu per year of steam, then "Building Boundary Value" of saving is 800 MBtu. If that steam is generated in an oil boiler of 80% efficiency, then "Post Boundary Value" is 800/0.8 = 1000 or 1000 MBtu of oil.

To get from the sample-building data of Figure 3-9 to a Form 1391, we assume that within a single folder energy consumption and costs are proportional to floor area. As an example, we extend the results of weather stripping to the ten units in the first entry of Figure 3-1, Buildings 2650 through 2659.

$$33 \text{ MBtu/yr} \times \frac{2073 \text{ ft}^2}{1588 \text{ ft}^2} \times 10 \text{ units} \quad = \quad 431 \text{ MBtu}$$

The 33 MBtu/yr is the energy savings in the sample which has 1588 ft^2 of floor area, and the 10 units have a mean floor area of 2073 ft^2.

$$\$220 \text{ annual savings} \times \frac{2073 \text{ ft}^2}{1588 \text{ ft}^2} \times 10 \text{ units} \quad = \quad \$2872/\text{yr for } 10.$$

$$\$444 \text{ retrofit cost} \times \frac{2073 \text{ ft}^2}{1588 \text{ ft}^2} \times 10 \text{ units} \quad = \quad \$5796 \text{ for the } 10.$$

Again, the $220 and $444 are savings and costs for the sample, Building 5410, and the $2872 and $5796 are savings and cost for the ten buildings, Nos. 2650 through 2659. Ratios such as energy-cost and benefit-cost remain constant because numerator and denominator always change by the same ratio.

3.3 Analysis of Radiant Heating Buildings 9570 and 9580

The study on alternative heating schemes for two large industrial buildings at the Logistics Center at Fort Lewis developed four alternatives for consideration. These are as follows:

1. Complete replacement of the buildings' heating systems with gas infrared units

2. Complete replacement of the buildings' heating systems with electric infrared units

3. Supplementary use of gas infrared units

4. Supplementary use of electric infrared units

Overall results were presented in Figure 2-3.

The most attractive in terms of rapid payback is the implementation of spot or area heating with gas fired infrared heaters (shown as Project 3). This, in part, is caused by the favorable natural gas service costs supplied by Washington Natural Gas Company. Presently, an 8-inch natural gas supply exists on North "L" Street in the Logistics Center. A service line could be installed running northwest on Prescott Avenue for approximately 2500 feet to the two buildings.

The installation of gas units likely would employ high intensity units (open flame) in the vehicle repair areas with low intensity (pipe enclosed burners) systems over the machine shop areas, parachute rigging areas, and similar work places. The costs used would allow implementation of either system or a combination of the two.

Although use of gas radiant spot heating appears warranted, it must be cautioned that successful use of the scheme depends upon careful placing and application of the units or system and acceptance of the system by the building personnel (users). The first hurdle will be overcome with proper design and adjustments. The second can be more difficult as certain shortcomings can exist in maintaining comfort with infrared heat. Personal prejudice and psychological or physiological concerns can defeat the proper use of the equipment. The possible complaints with this method of heating result from the lack of maintaining comfort levels of the air. If the person is not in direct view of the heater or not properly clothed, the comfort level can be diminished. Thus, it is suggested that some testing be done by a partial installation to determine attitudes before committing the entire retrofit. This possibly could be done in an area where natural gas is available (another building) or with a temporary system utilizing propane. If the users will accept the system, this project is worth implementing.

It must be cautioned that individual units may be required to be turned off in cases where flammables are stacked too close to heaters. Individual unit override switches must be provided.

Project 4 investigated the same application as Project 3 using electric infrared units instead of gas. The major deterrent to this scheme was the cost of power distribution and service disconnects to the units. The maintenance costs are higher with electric units due to the shorter operating life of the heating elements. The advantage of the use of electrical units is the possible portability of the units. This can serve to overcome some of the complaints mentioned above. Also, the implementation of sample or test units would be simpler with the electrical units.

The implementation of Projects 1 or 2, which would completely abandon the existing steam system, cannot be recommended. Primarily the payback for these schemes is not as attractive as the spot heating projects. Further, abandonment of the existing boiler plant will affect other nearby buildings as this plant (3LC) serves as primary heating source for several buildings. Other arrangements for supplying heat for these other facilities would be needed, although no monetary value for these provisions has been included in the project calculations.

This system of radiant spot heating can be applied in other locations. The basic study includes an analysis of portable electric radiant heating in vehicle maintenance buildings in which only one or two bays out of six or eight total are in use at any one time. If radiant spot heating can allow the general heat level to be reduced to 40° or 50°, savings can be substantial.

3.4 Energy Monitoring and Control System

The last study increment was assessment of the potential of an EMCS for Fort Lewis, Yakima Firing Center and Vancouver Barracks. Camp Bonneville was not considered as it has only a few small buildings used infrequently. The study was based upon the same folder/sample system and data used throughout this study series. We assumed that the three major central plant improvements for which Forms 1391 have been submitted were in place. We added folders and samples for a number of buildings, principally the Third Brigade area, which were built after the 1975 base period of the original study and not previously included.

We updated heat loss calculations for all of the samples to account for energy conservation improvements accomplished after the original survey. In consultation with DFAE, a set of planned improvements was identified and the calculations updated with the assumption that the improvements would be made. From this new base, energy savings from controls modifications were calculated and cost of an EMCS to perform the tasks was estimated.

Results indicate the overall project is not feasible, that discounted benefit/cost ratio is less than 1.0. Because none of the installations have significant amounts of air-conditioning and because electricity rates are low by national standards, almost all savings are from reductions in space heating energy. This substantially reduces the usefulness of EMCS relative to the situation in warmer, more humid climates or in climates with more extreme summers and winters.

The system concept included six subnetworks serving relatively homogeneous geographic areas at Fort Lewis and one subnetwork at each of the two subinstallations. Results were evaluated for each of the eight, prorating central system costs. For those which had benefit-cost ratios near to or greater than 1.0 in the initial analysis, alternative analyses were performed. Only two of the subnetworks consistently had benefit-cost ratios greater than 1.0. These were North Fort Lewis and Yakima Firing Center, both of which were oil fueled at the time of the analysis.

The poor cost-effectiveness results from three characteristics of the three posts:

a. Mechanical cooling is uncommon.
b. Electricity prices are low.
c. Coal is specified for the largest loads.

Net annual benefits of each concept analyzed was a small difference between relatively large annual energy savings and operating costs. A relatively small increase in energy cost savings will make substantial increase in net annual benefits in most instances. Nationally, EMCS dollar savings in the cooling season usually exceed the dollar savings in the heating season. If this concept had included control of total air-conditioning systems instead of just heating, and if the cost of saved electricity were valued at about the national average, then the system would be cost-effective. However, there is little cooling and electric rates are low, hence the system does not pay.

A lesser problem was the assumed use of coal throughout most of Fort Lewis except North Fort Lewis and family housing areas. The area east of Gray AAF is now served with No. 6 oil, for example. If the EMCS for that area were evaluated against oil price instead of coal price, the discounted benefit/cost would be 1.18 instead of 0.02 (DTL 1110-34-8 escalation rates).

In terms of Fort Lewis planning, even this benefit/cost ratio of 0.02 is optimistic, however. That plant is to use solid waste from Ft. Lewis and McChord AFB as fuel. Net benefit is zero for energy saved from that source. To keep the analysis from becoming trivial, we assumed that waste energy saved at the plant could displace coal at other plants, hence the eventual effect is savings of coal. Savings for the area were therefore evaluated at coal prices. However, additional investment would be needed to make other plants capable of burning waste. If this additional investment were taken into account, B/C would be even smaller.

3.5 Discussion

As Table 2-1 shows, projected savings of energy made from these analyses are quite large. Most of the savings came from the "Big 3" conservation measures of roof/ceiling insulation, infiltration control, and temperature adjustment (setback in unoccupied and sleeping hours).[2] This is because most buildings are simple, with simple systems, and most are twenty years old or more. Consequently, roof/ceiling insulations inadequate or nonexistent, windows and doors no longer fit tightly, and thermostats have no clocks and are easy to reset. Few buildings are cooled, and few are even mechanically ventilated beyond toilet exhausts.

The biggest savings come from temporary buildings, particularly at North Fort Lewis where the sample buildings had no interior finish and very loose windows. When starting with just studs, siding and sheathing in the walls and equally simple floors and ceilings, the combination of insulation, weatherstripping and temperature adjustment is inexpensive and very effective.

After the "Big 3" conservation measures, we found a mix of improvements applicable in special situations. For example, we found automatic flue dampers to be cost-effective on boilers and water heaters with atmospheric (naturally aspirated) gas burners, particularly if located

[2] Because these conservation measures are strongly interactive, they were analyzed together to guard against projecting savings that were too high.

in the heated space. Potential for effective use of flue dampers is limited at Fort Lewis because of the preponderance of forced-draft oil-fired plants. At the extreme are the many oil-fired, forced-air household furnaces located in unheated space, a poor application for flue dampers.

In these applications, the steady-state heat transfer mechanism requires two convection loops. One is a flow from the heated space through the furnace heat exchanger, blower and filter back to the heated space. The other is from outside through the burner, furnace heat exchanger and stack. The first loop is driven by inside air being cooled in the heat exchanger and the flow must overcome the resistance of the air filter and stopped blower as well as the general ductwork and heat exchanger. The second loop is driven by outside air being heated in the heat exchanger and by stored heat in the stack. The flow must overcome the resistance of the forced-draft burner, heat exchanger and stack. A flue damper will stop the loss of heat from loop-to-loop in the heat exchanger by stopping flow in the second (outside) loop. The savings are small because the rate of loss is small.

In contrast, a boiler or water heater loses heat through only one loop, the air flowing in through the burner, through the heat exchanger, and out the stack. If the burner is atmospheric, it will offer little resistance to flow relative to the resistance of a forced-draft burner. The heat exchanger, will transfer large quantities of heat from water at 140°F or greater (over 200°F in some heating boilers) to the cooler air. A flue damper that stops flow in this loop saves relatively large quantities of energy.

FIGURE 3-1
FORT LEWIS BUILDING DATA EXAMPLE

Folder No./ Sample No.	Buildings Represented	Number of Buildings	Area Sample (Square Feet)	Area Mean (Square Feet)
6-5410	2650-59	10	1,588	2,073
6-5410	5401-85, 5523-66, 5601-79	208	1,588	1,588
6-5410	6301-88, 6505-98, 6601-98, 6701-22, 6727-28, 6731-34, 6737-38, 6741-62, 6769-98, 6802-72, 6901-82	524	1,588	1,584
6-5410	8011-40, 8042-49, 8160-90, 8192-95, 8201-04, 8206-11, 8217, 8219-35, 8238-41, 8301-17, 8319, 8321-23, 8325-27, 8229, 8232, 8234-35, 8237-45, 8347, 8349-57, 8359, 8361, 8363, 8365, 8380-98, 8401-25, 8427, 8429, 8431-58, 8462-98, 8501-16, 8518, 8520-21, 8523, 8525, 8527-28, 8530, 8541, 8543, 8545-79, 8608, 8610, 8612, 8614, 8620, 8622, 8624, 8626, 8628-31, 8633-46, 8648, 8650, 8652, 8654, 8656-65, 8662, 8664, 8667, 8669, 8671-73, 8675-95, 8735, 8737, 8739-50, 8801, 8803-12, 8814-15, 8817, 8823, 8825-33, 8845-55, 8861-67, 8871-84	456	1,588	1,656
6-5410	9800-41, 9844, 9846-99	101	1,588	1,597

FORT LEWIS
BUILDING TYPES

SHEET ___ OF ___

CURRENT USE FH NCO

YEAR BUILT 1963

NO. STORIES 1

SQ. FT. AREA 1691

FOUNDATION CONC
WALLS WF
ROOF COMP

REMARKS 1H-O 1F 4BR

IDENTIFICATION NUMBERS

9816				
9817				
9824				
9825				

QUANTITY 4

S.O. # 00321-01

FIGURE 3-2
Example - Building List A

- FAMILY HOUSING, OFF
  - 1963, 1 STORY, IH·O
  - #8826 TO #8827
  - 1862 SQ. FT

CONC WOOD COMP
6 BLDS.
BEACHWOOD

- FAMILY HOUSING, OFF
  - 1963, 1 STORY, IH·O
  - #8827 TO #8852
  - 1712 SQ. FT

CONC WOOD COM
9 BLDS
BEACHWOOD

- FAMILY HOUSING, OFF
  - 1963, 1 STORY, IH·O
  - #8828 TO #8848
  - 1740 SQ. FT

CONC WOOD COM
6 BLDS.
BEACHWOOD

- FAMILY HOUSING, NCO
  - 1963, 1 STORY, IH·O
  - #9800 TO #9837
  - 1539 SQ. FT.

CONC WF COMP
18 BLDS.
MADIGAN

- FAMILY HOUSING, NCO
  - 1963, 1 STORY, IH·O
  - #9802 TO #9843
  - 1568 SQ. FT

CONC WF COMP
22 BLDS.
MADIGAN

- FAMILY HOUSING, NCO
  - 1963, 1 STORY, IH·O
  - #9816 TO #9825
  - 1691 SQ. FT

CONC WF COMP
4 BLDS.
MADIGAN

	Drawn By	Date
	Checked	Date
JOHN GRAHAM AND COMPANY ☐ JOHN GRAHAM COMPANY ☐ JOHN GRAHAM, ARCHITECT ☐	Job No.	
	Sheet 7	

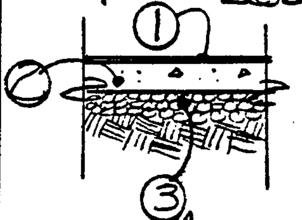
FIGURE 3-3
Example - Building List B

FOLDER # 6

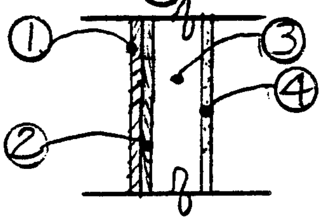
- PLANS AND ELEVATIONS:
  REFER TO DRAWINGS PROVIDED

- CONSTRUCTION:
  - ALL DIMENSIONS AS PER PLANS

1ST FLOOR:



FLOOR: ① 1/8" LINOLEUM
② 4" CONCRETE SLAB
③ 4" GRAVEL



WALLS: A1 ① 3/4" EXTERIOR WOOD SIDING
② 3/8" WOOD SHEATHING
B1 ③ 2"X4" WOOD STUDS (No insulation)
E1 ④ 1/2" GYPSUM WALLBOARD

NOTE: NO INSULATION IS USED IN ANY EXTERIOR WALL.

WINDOWS: KITCHEN, UTILITY, BEDROOMS: ALUMINUM FRAME, FIXED WITH LOWER CASEMENT (REFER TO DRAWINGS) SINGLE PANE 1/8". NO WEATHER STRIPPING AIR LEAKAGE AT SEAL POINTS.
ALL WINDOWS 47" ABOVE FINISHED FLOOR.
LIVING ROOM: FIXED WOOD FRAME WITH LOWER ALUMINUM FRAME CASEMENT (REFER TO DRAWINGS) ALL SINGLE PANE 1/8". CASEMENT HAS AIR LEAKAGE AT SEAL POINTS, NO WEATHER STRIPPING.

NOTE: NO USE OF STORM WINDOWS

FT. LEWIS, FAMILY HOUSING, NCO & OFF BLD # 5410, 1 STORY, CONC. WD COMP	Drawn By	Date 12/27/78
	Checked	Date

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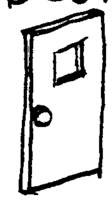
JOHN GRAHAM, ARCHITECT ☐

Job No. 5410

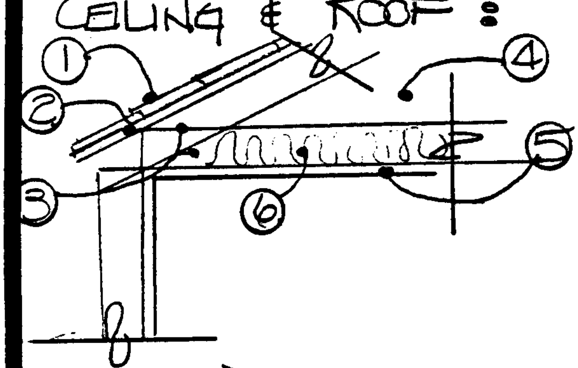
Sheet 1

FIGURE 3-4
Architect Field Notes sheet 1

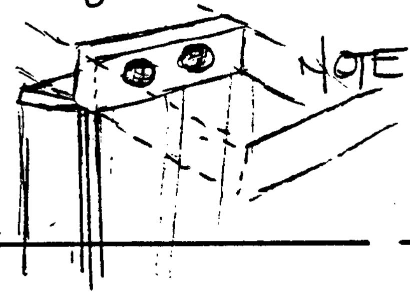
DOORS: 

SOUTH DOOR: SOLID WOOD WITH GLASS PANEL INSERT (GLASS 11 1/2" x 11 1/2" SINGLE PANE FIXED REFER TO DRAWINGS FOR STYLE. NEW FOAM WEATHER STRIPPING ALONG EDGES*. ALUMINUM OVERLAP AT THRESHOLD. PRETTY GOOD SEAL.
NORTH DOOR: SOLID WOOD, SAME WEATHER SEAL AS SOUTH DOOR.* THIS DOOR HAS A NEW STORM DOOR*

CEILING & ROOF:



1. ASPHALT SINGLES
2. 1/2 WOOD SHEATHING
3. 2x6 & 2x4 JOISTS.
4. AIR SPACE
5. 1/2" GYPUM WALLBOARD
6. 2" INSULATION ALUM. BACKED LAYIN.



NOTE: ATTIC IS VENTED WITH SCREEN HOLES ALONG JOIST WALL EDGE.
Roof Ventilator also present.

GENERAL: NO INSULATION IN EXTERIOR WALLS, NO USE OF STORM WINDOWS OR DOORS IN GENERAL.
THESE BUILDINGS ARE BEING UPDATED NEW BLOW-IN INSULATION IN ATTIC 6" AVGERAGE, NEW SPRAY ON PLASTER CEILINGS, NEW WEATHER STRIPPING ON DOORS.

* CHECK DATE

	Drawn By	Date 12/27/7	
	Checked	Date	

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Job No. 5410
Sheet 2

FIGURE 3-5
Architect Field Notes sheet 2

LIGHTS: 13 INCADESCENT FIXTURES IN 3 BEDROOM
ASSUME ONLY ONE LESS FOR
2 BEDROOM.

NOTE: ALL ATTIC DIMENSIONS, OVERHANGS,
ETC TAKE FROM DRAWINGS.

* PLEASE NOTE: ALL THREE-BEDROOM HOMES ARE A COMBINATION OF A 2 BEDROOM PLAN WITH A THREE-BEDROOM OPTION. NO FEASIBLE WAY OF TELLING HOW MANY ARE TWO BEDROOMS OR THREE-BEDROOMS WITH PRESENT INFORMATION.

	Drawn By	Date
	Checked	Date

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JOHN GRAHAM COMPANY ☐
JOHN GRAHAM, ARCHITECT ☐

Job No. 5410
Sheet 3

FIGURE 3-6
Architect Field Notes sheet 3

Residence 5410

Single Family, Concrete Slab on grade. wood siding. Composition roof.

Furnace - Oil-fired ducted hot air manufactured by Lenox Ind. # OIIR-105. Input 105,000 Btuh, bonnet capacity 84,000 Btuh. Max. firing rate 0.75 GPH. Draft @ 0.03" H_2O. Flue w/ draft control counter balance type. System is controlled from T'stat located in hall off living room.

Oil storage tank is 300 gal.

Hot water heater is National Delux # 10 H 71. Upper element 2500 w. Max. watts 4500. Lower element 2000 w. Working pressure 150 PSI

Electrical meter blank on outside of unit. Circuit Breaker Panel is located in Kitchen. Electric dryer outlet. Garbage disposal 115 V., 5.4 amps, 1/3 HP @ 1725 RPM 60 ~ 1 ph. Electric range is 11.7 KW @ 240 V and 9.0 KW @ 208 V. Ceiling exhaust over range.

FIGURE 3-7
Engineer Field Notes

Figure 3-8
Baseline Data - Example

FOLDER NUMBER: 6 **BUILDING NUMBER:** 5410
BUILDING FUNCTION: Family housing, half duplex

BUILDING PARAMETERS

"U" Value (Btu per hour per foot square per degree F)

Roof/Ceiling: 0.38/0.13
Exterior Wall (composite): 0.38
Floor: 0.09
Windows: 1.15
Doors: 0.32

Window/Floor Area Ratio: 0.13:1
Window/Total Load Ratio:

Peak Heat Gain – Btu/hr:
Peak Heat Loss – Btu/hr: 53,200
Infiltration – MBtu/yr: 43

ANNUAL USE, BUILDING BOUNDARY VALUE

USE NO. 1: LIGHTING — **Fuel:** Electricity — **Electric kWh:** 2,508

USE NO. 2: COMFORT HEAT — **Fuel:** Oil — **Medium:** Hot Air — **Fossil MBtu:** 173 — **Electric kWh:** 0

Devices to Condition Medium: Oil furnace, FA
System Transporting Medium: Duct
System Exchanger Surface:
Medium Storage:

USE NO. 3: REFRIGERATION — **Fuel:** Electricity — **Medium:** NA — **Fossil MBtu:** 0 — **Electric kWh:** 1,830

USE NO. 4: AIR-CONDITIONING — **Fuel:** None — **Medium:** — **Fossil MBtu:** 0 — **Electric kWh:** 0

Devices to Condition Medium:
System Transportation Medium:
System Exchanger Surface:
Medium Storage:

USE NO. 5: DOMESTIC HOT WATER — **Fuel:** Electricity — **Medium:** NA — **Fossil MBtu:** 0 — **Electric kWh:** 11,252

TOTAL ANNUAL USE, POST BOUNDARY VALUE

Gas Therms:
Oil No. 2 **Gallons:** 1247
Electricity kWh: 15,590

Figure 3-9

Conservation Measurement Summary - Example

FOLDER NUMBER 6 **BUILDING NUMBER** 5410

BUILDING FUNCTION Family Housing, Half Duplex

ANNUAL SAVINGS, POST BOUNDARY VALUE

ENERGY CONSERVATION RETROFIT MEASURE	FUEL TYPE	ENERGY REDUCTION	COST SAVINGS	RETROFIT COST	ENERGY/COST
1. Lighting Modifications	Electricity				
2. Building Envelope and HVAC Control Modifications					
• Insulation – Roof	Oil #2	18 MBtu	$117	$316	55
• Insulation – Wall					
• Weatherstripping	Oil #2	33	$220	$444	74
• Window Replacement					
• Temperature Adjustment	Oil #2	25	$165	$ 81	305
• Zone Control					
3. Flue Dampers and Electric Ignition					
• Domestic Hot Water					
• Comfort Heating					

SUMMARY OF SAVINGS, POST BOUNDARY VALUE

Electricity			
Distillate Oil	75 MBtu	$503	$841
Residual Oil			
Natural Gas			

4.0 CENTRAL PLANTS

Fort Lewis is served with a mix of individual and central heating plants. Most of the central heating plants burn residual oil; two small plants, Nos. 1 and 7, burn distillate oil. Figure 4-1 shows the service areas of the existing major plants, all fired with residual oil.

Plant Nos. 9, 10, 11 and 14 are the modern plants. Nos. 9 and 10 are high temperature hot water, the others steam. Nos. 10 and 11 are physically contiguous. All four have substantially greater capacity than they require for the connected loads.

Plant No. 5 serves the post laundry and has much more capacity than needed. Plant No. 6 was built in the early 1940's as a coal-fired plant and later converted to oil. Plant No. 3LC (for Logistics Center) is an older plant that is part of Building 9580. It is scheduled for enhancement to serve as interim plant for the new Madigan AMC. It is also interconnected with Plant No. 5LC, a plant that has boilers built in 1904. It should be abandoned, but must be fired in winter periods when No. 3LC cannot carry the connected load.

Much of Yakima Firing Center is served with a series of interconnected steam plants fired with residual oil. Originally three identical plants, one has been abandoned as unneeded and one is used only in peak winter periods and as standby.

4.1 Biomass Energy Plant Concept Study

The Biomass Plant study was added to the Basewide Energy Use Plan scope in September 1979 in response to an OCE interest in examining the potential of using logging residues on those Army posts with substantial silviculture operations. As the largest producer of timber revenue the previous year, Fort Lewis was chosen as a test case.

The plant was to be a steam - electricity cogenerator fired with wood residues from on-post and off-post sources. It was to supply on-post heating loads and, as available, off-post steam loads. It was to be owned and operated by a publicly owned electric utility, with the Army providing land, security, and fuel from on-post sources and buying steam. The utility would add the electricity produced into its overall supply. This last element has a significant effect on the concept design and economics and is often - usually - not understood by readers outside of the Pacific Northwest.

The extensive regional hydroelectric system allows present rates to be very low, less than 1 cent per kWh from Tacoma City Light to the Army at the time of this study. If an Army-owned cogenerator were examined on the basis of displacing purchased electricity (the usual practice elsewhere in the U.S.) it would have very poor economics. However, a utility looking to meet load growth must deal with marginal rates that are much higher, over 4-1/2 cents per kWh at the time of the study.

While the Army could not make electricity cheaper than the 1 cent it was paying, the utility would consider purchase of 4-cent electricity in lieu of 5-cent electricity from other sources. The Army's benefits would come in the form of steam at lower cost than the oil-fired boilers in use and in new revenues for waste wood.

The concept was derived by listing all of the heating loads on or near the cantonment, then discarding those that would require large unit costs to connect. At one extreme, the loads least expensive to connect were those on existing large steam and hot water distribution systems on Fort Lewis or McChord AFB.[3] At the other extreme, the loads most expensive to connect were the newer family housing and the temporary buildings of North Fort Lewis, where many feet of main and lateral piping would be necessary for each small building, each small increment of load.

The resulting system is shown in Figure 4-2. Essentially it serves the major buildings of McChord, Logistics Center, new Madigan AMC, old Madigan buildings converted to office use, the barracks and other facilities around Gray AAF, the major buildings in the western cantonment, and the old family housing.[4] Total peak steam load for this system was estimated to be 372,000 lb/hr. Adding distribution losses and plant use, a maximum steam rate of 450,000 lb/hr was projected.

The basic heat loss calculations of the folder/sample system were used to project loads. Because the basic energy-in-buildings study had not progressed to the point of having good conservation data, an across-the-board 25% reduction was assumed as the effect of future conservation.

To meet this load, the plant concept included a steam generator with steam exit conditions of 1250 psia and 950°F. The steam system was supplied with two backpressure turbines of 160,000 lb/hr each with exit conditions of 200 psia, saturated, and with maximum production of nearly 15 MW of power. On those few occasions when larger steam supply was needed, a pressure-reducing valve and desuperheater would be used. A condensing turbine of 80,000 lb/hr with inlet condition of 200 psia, saturated, was included to provide operating flexibility.

---

[3] McChord AFB is adjacent to Fort Lewis near the Lewis cantonment. Its major steam plant is larger than any at Lewis and is fired with natural gas and light oil, hence has potential for large savings.

[4] Older, larger houses for field grade and general officers use much more energy than newer, smaller houses for company grade and NC officers. Moreover, most have old coal boilers converted to oil. Net savings per house were considered large enough to warrant inclusion.

Figure 4-3 summarizes available fuel to fire the plant within an identified range of 194,000 to 275,000 wet tons/year. Most of the fuel must come from off-post sources, primarily U.S. Forest Service lands. The institutional problems involved discouraged further consideration of the project.

Respresentative economic projections are presented in Figure 4-4. Much has changed since these projections were made. For example, the baseline oil cost projection of $1 per gallon was considered too low by many in late 1979 and early 1980. Now, it is obviously too high.

4.2 Solid Fuel Central Plant Studies

4.2.1 Increment E

In the Increment E study, we examined the feasibility of substituting solid fuels for much of the fuel oil and natural gas now used at Fort Lewis. As a result of our own investigations in the Biomass Energy Plant Concept Study, we knew the amount of wood fuel available from Fort Lewis. As a result of the Civil Engineering Research Laboratory work, we knew the amount of solid waste fuel available from Fort Lewis and McChord AFB together.

The baseline concept included five new plants with service areas as shown in Figure 4-5. Sufficient wood and waste fuel was available for one plant, and Plant B was chosen. It is most remote from railroad access for coal delivery. Because wood and waste will travel by truck, lack of rail access is not important. The baseline included substantial allowances for a new Madigan AMC and for another brigade area north of existing 3100 Block. The basic Folder/Sample system was used to build up load projections for each plant service area and allowances were made for recent and projected energy conservation improvements. North Fort Lewis was not included in any system; its multiple temporary buildings with only about 30% average occupancy do not warrant the major capital expenditure.

An alternative of a single, large plant serving the same loads as the five was also examined.

Our directions for the study included the assumption that all of the plants would be new and that the existing plants would be demolished. That assumption downgraded benefit-cost in the Plants B and D systems because both have modern, usable buildings and some modern boilers that can be converted to wood and/or coal firing.

Figure 4-6 summarizes the analyses of the plant concepts. Two of the five plants show benefit/cost rations (B/C) of over 2, two of the five and the single plant show B/C between one and two, and one of the five shows B/C less than 1. Of the four plants with B/C over 1, the major difference is in the net change of O&M cost. Large coal plants are intensive in operating labor and in maintenance. However, Plants A and E both displace a number of smaller central plants and individual heating plants that are attended at least part-time and that have significant maintenance cost themselves. Therefore, the net increase of O&M cost is relatively smaller. Plant B is the solid waste and wood plant, and the labor and maintenance requirements are large, substantially offsetting the benefits of the cheapest fuels.

Because the Plant C distribution system is totally new and serves many small loads of modern family housing, its capital cost is higher than the rest. Because it displaces no existing central plants, its net increase of O&M is quite high. These two factors offset the large fuel savings from displacing expensive distillate oil. Most of the new distribution added to Plant D has the same disadvantage of large capital cost. However, the housing served by Plant C has modern forced-air heating plants, whereas about half of the housing served by Plant D has older, inefficient steam and hydronic plants. Housing units to be served by Plant D are much larger, as well. Conversion costs per unit are, therefore, much less, and the energy savings greater on the Plant D housing.

The single plant is, of course, an amalgam of the advantages and disadvantages of the five plants. It is less labor intensive for plant operations than the set of five, but requires addition of a long network of large steam and condensate lines. This adds both capital and maintenance costs.

4.2.2 Renewable Resources; Conflicting Recommendations

The Basewide Energy Use Plan study included an examination of renewable energy sources. At Fort Lewis, the major renewable resources were identified to be wood residue and solid waste. The Basewide study also included an examination of conflicting recommendations on consolidation or replacement of existing boiler plants. Our recommendation was to pursue consolidation and conversion to coal and renewable fuels, baseloading converted boiler plants with solid waste, supplementing the waste with wood, to the extent available, then completing the needs with coal.

Economic results of a cursory analysis of the option are shown in Figure 4-7. We caution the reader that the analysis was not a discounted life cycle cost analysis but a first-year net cash flow analysis that did not provide for cost escalation before and during construction and included no contingencies or design costs.

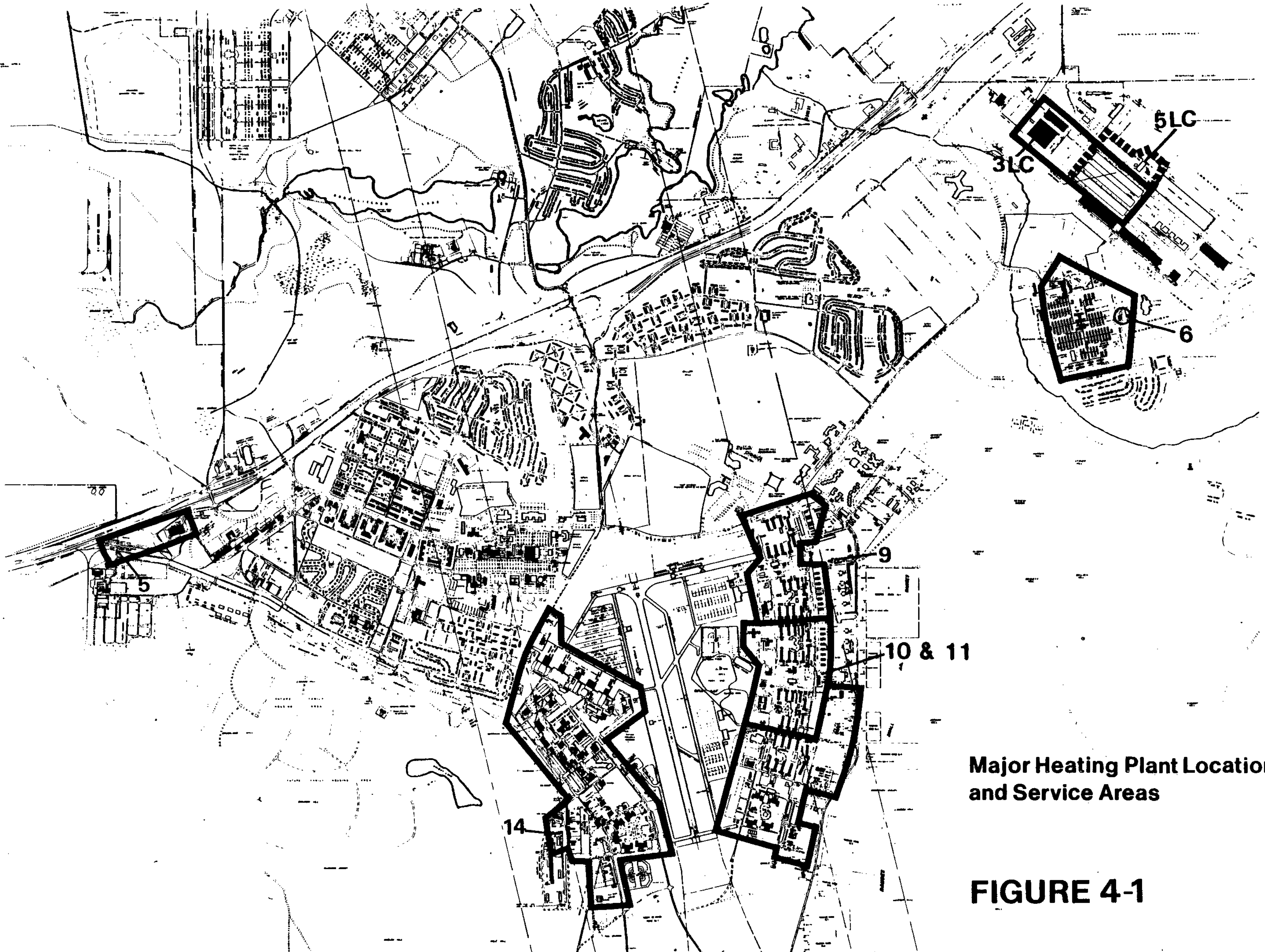
The systems are similar to some discussed earlier. Plant No. 11 was to be converted and expanded to serve the area now served by Plants Nos. 9, 10 and 11 (Figure 4-1). It is similar to Plant B of Increment E except that it reuses the existing building and boilers and does not include capacity for new loads.

Plant No. 14 proposal also includes reuse of existing boilers and building. It was to serve the area served by Plants D and E of Increment E (Figure 4-5).

4.3 Basewide Plan for Central Plants

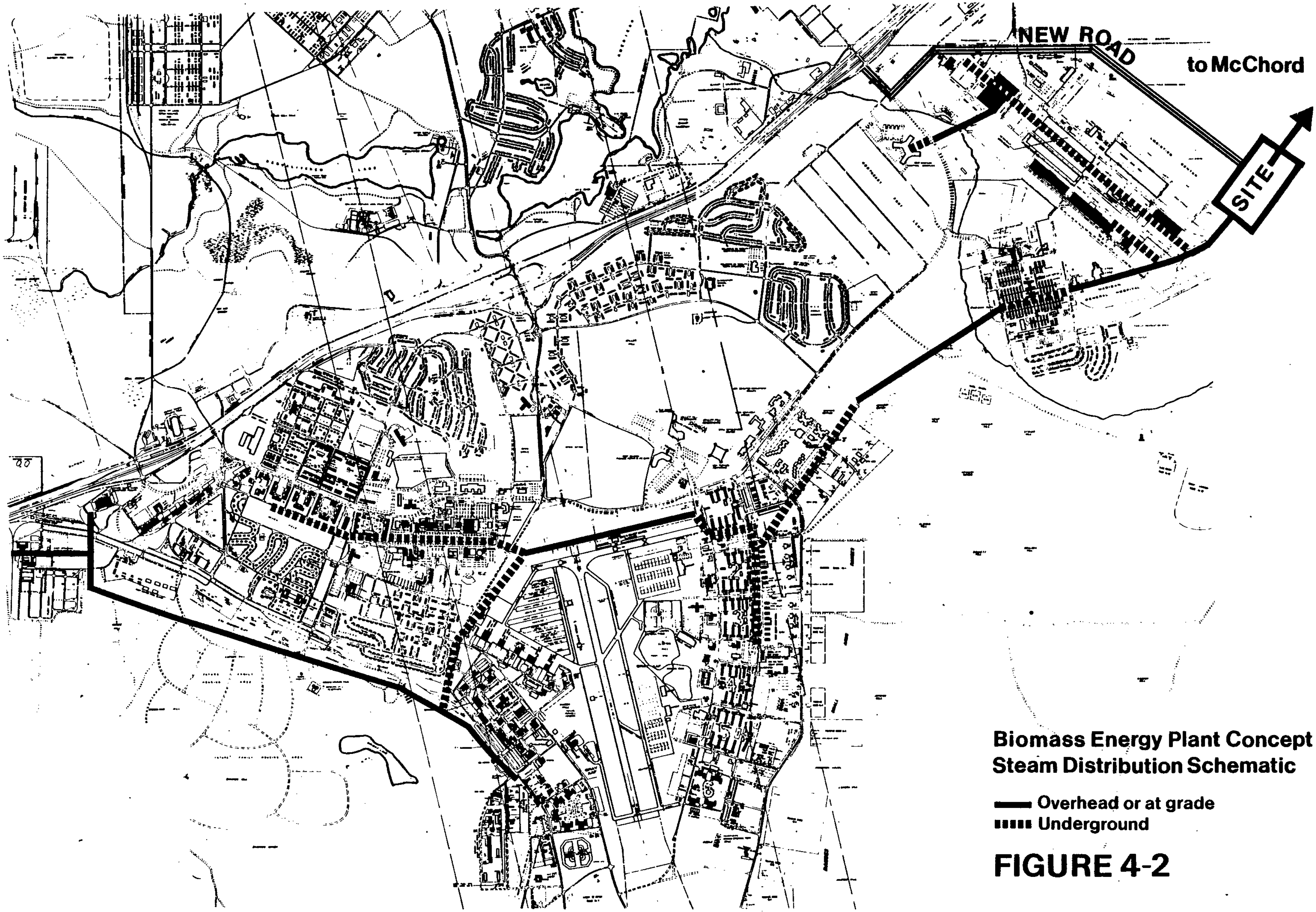
While the various studies proceeded, decisions were being made and implemented at Fort Lewis. Plant No. 5 is to be demolished and its boilers replaced with new, smaller boilers, oil fired, located at the laundry. The CERL concept for conversion of Plant No. 11 to exclusively use solid waste fuel was chosen and a Form 1391 submitted. The decision was made to proceed with design of the new Madigan AMC, and Fort Lewis submitted a Form 1391 for a coal-fired plant that is essentially Plant A of the Increment E concept. The decision was made to not use wood residues from the post.

With these decisions made, a Form 1391 was prepared for conversion of existing Plant No. 14 to coal and expand its service area to displace oil and gas fuels up to the limit of Plant 14's steaming capacity. Because the plant has 4 boilers capable of 30,000 lb/hr of steam each, a peak load of 90,000 lb/hr is appropriate. Resulting service area is shown in Figure 2-4.



Major Heating Plant Locations and Service Areas

FIGURE 4-1



Biomass Energy Plant Concept
Steam Distribution Schematic

FIGURE 4-2

Biomass Energy Plant

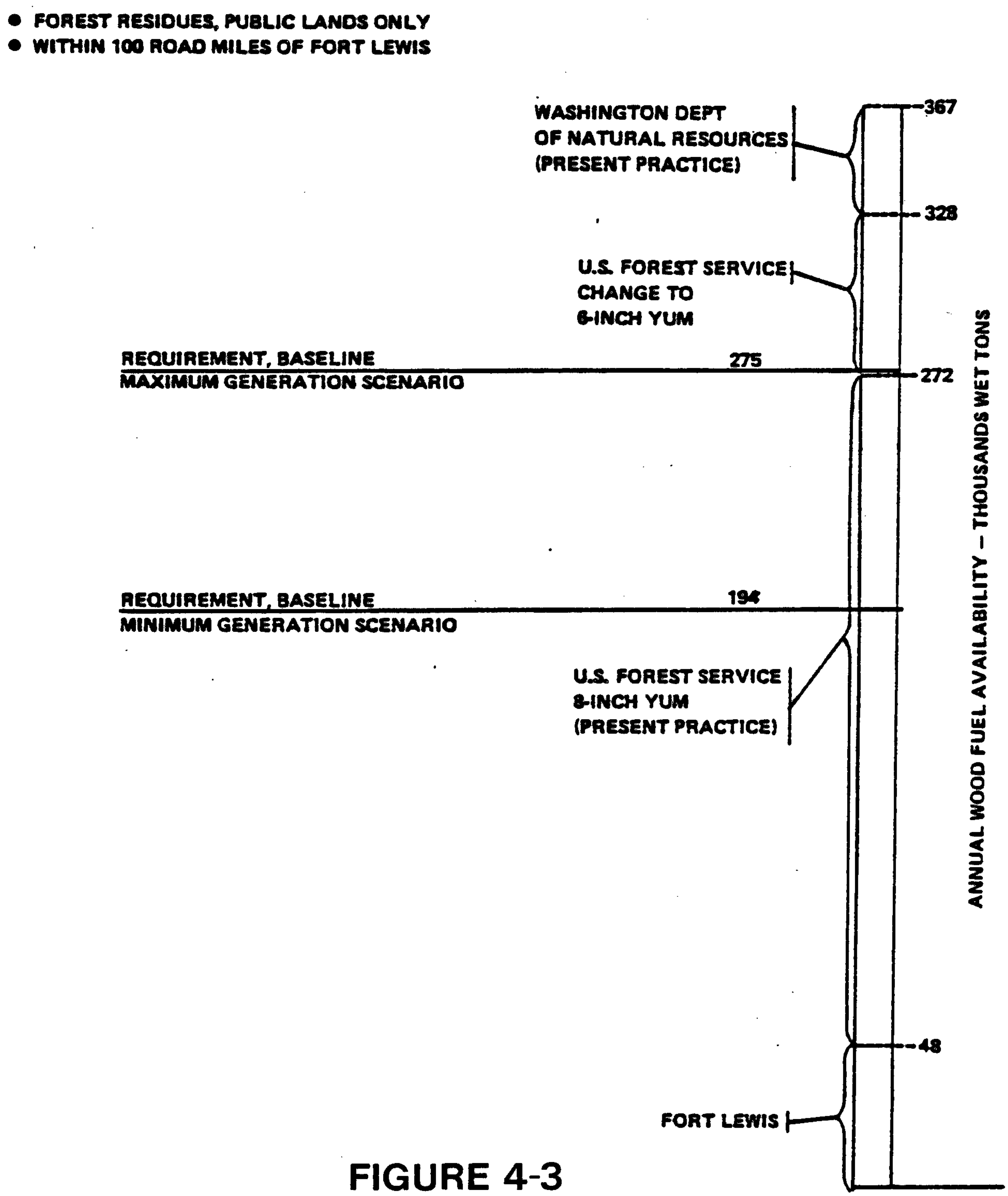
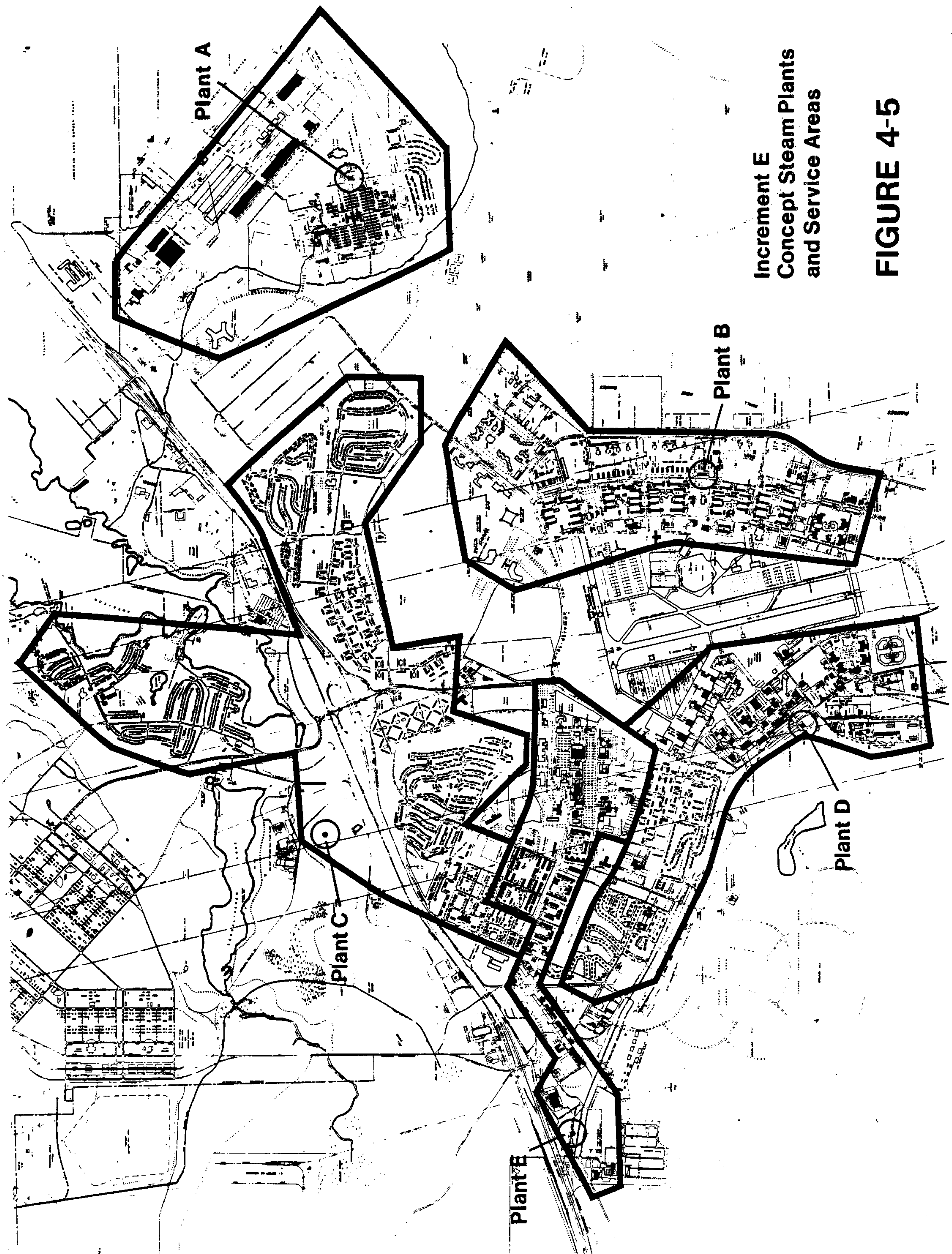


FIGURE 4-3

FIGURE 4-4
BEP MINIMUM GENERATION SCENARIO
COSTS AND BENEFITS, FIRST YEAR
(in millions of 1980 dollars)

	Optimistic	Baseline	Conservative
Cost to Government	$ 2.06	$3.28	$ 3.67
Cost to Utility	7.83	9.01	10.42
Cost, Total	9.89	12.29	14.09
Savings to Government	12.06	10.22	8.92
Revenue to Utility	2.88	2.16	1.44
Benefit, Total	14.94	12.38	10.36
Net Benefit (cost)	$ 5.05	$ 0.09	($ 3.73)
Oil Price, Dollars/Gallon	$ 1.20	$ 1.00	$ 0.80
Electricity Value, Mills/Kilowatt-Hour	60	45	30
Wood Fuel Cost, Off-Post, Dollars/Wet Ton	$12.00	$17.65	$22.65
Plant Capital Cost	$47.31M	$47.31M	$54.41M
Amortization Period, Years	$11.00M	$20.70M	$23.80M
Underground System Type [1]	Concrete	Conduit	Conduit
Fuel from On-Post Sources, Wet Tons	60,000	48,000	36,000

[1] Concrete refers to poured-in-place insulating concrete for underground piping; conduit refers to more expensive prefabricated piping systems.



Increment E
Concept Steam Plants
and Service Areas

FIGURE 4-5

FIGURE 4-6
SUMMARY OF RESULTS
SOLID FUEL CENTRAL PLANT STUDY
(Thousands of Dollars)

Plant System	Major Service	Fuel	Capital Cost (1)	Net Change O&M Cost (2)	Net Change Fuel Cost (3)	Discounted Benefit/Cost Ratio (4)
A	Madigan AMC Logistics Center	Coal	$ 21,409	$ -7,118	$ 63,617	2.64
B	Barracks with Mess Motor Vehicle Shops Administration	Wood, Solid Waste	29,243	-19,599	68,251	1.66
C	Family Housing	Coal	45,036	-32,818	71,930	0.87
D	Barracks with Mess Hangars Motor Vehicle Shops Family Housing	Coal	23,646	-14,277	47,621	1.41
E	Laundry Barracks with Mess Motor Vehicle Shops Administration	Coal	19,018	-8,773	49,165	2.12
Single Plant	All Areas Above	Coal, Wood, Solid Waste	127,037	-125,629	300,131	1.37

(1) At Midpoint of Construction, 1986
From Line 1.d, Tables 5-3 through 5-8
(2) At Beneficial Occupancy Date (BOD), 1987
From Line 2f, Tables 5-3 through 5-8
(3) At BOD, 1987. From Line 3.e, Tables 5-3 through 5-8
(4) For 25 years beginning at BOD

FIGURE 4-7
RENEWABLE FUEL ECONOMICS
HEATING PLANT NOS. 11 AND 14
(in millions of 1980 dollars)

	Capital Cost[1]		Annual Cost	
	Plant No. 11	Plant No. 14	Plant No. 11	Plant No. 14
Convert existing boiler	1.20	1.20		
New controlled combustion incinerators with heat recovery boilers	1.30	2.00		
Added distribution system	0.50	2.55		
Buildings, miscellaneous equipment controls	0.73	1.25		
TOTAL CAPITAL	3.73	7.00		
Amorization of capital at 12%, 25 years			0.47	0.89
Wood fuel cost[2]			0.21	0.27
Oil conserved			(1.85)	(1.99)
Overhead and maintenance cost (other than fuel); net change			(0.19)	(0.20)
NET ANNUAL COST (Benefit)			(2.04)	(2.19)

1 Cost does not include investment in mobile equipment for processing and transporting hogged fuel; those are in wraparound "wood fuel cost."

2 Net change of solid waste fuel collection and handling costs is assumed to be zero.

5.0 OTHER PORTIONS OF THE PLAN

5.1 Utility Analysis, Sanitary Sewage and Disposal System

This Supplement to the Utility Analysis, Sanitary Sewage and Disposal System, reports the work done to locate and define infiltration/ inflow areas and problems existing in the sanitary sewer collection system. It recommends solutions that are compatible with plans for future construction.

Data collected indicates that trunk lines and major laterals serving the areas southeast of Interstate Highway 5 have offset joints, cracks, root intrusions, and other defects which would cause exfiltration in summer months and infiltration during periods when ground water levels rise to the sewer invert elevation. Water production and consumption cannot be correlated with sewage treatment plant effluent volume. General rehabilitation of the system is indicated. A sanitary sewer television survey of Trunk Lines A and B is recommended to determine pipes requiring replacement or repair, and pipes shown to be cracked or having offset joints should be replaced or corrected by lining or other means.

Within the oldest section of Fort Lewis Military Reservation, storm inlets and roof drains are directly connected to the sanitary sewer system. Areas undergoing demolition of buildings to the foundation level are left with open stubs to the sanitary sewer. These conditions contribute to storm water volume and should be corrected. In general, unused lines should be plugged.

Daily records of sewage treatment plant activity indicates seasonal influent variations of 7 million gallons per day (MGD) during the winter months, to 2 to 3 MGD in the dry summer months. Influent volume differences of 2 MGD over a 24-hour period have been recorded with no apparent reason for the change (September 1978). Peak capacity of the sewage treatment plant at Solo Point is 14 MGD. The 7 MGD processed during winter months poses no problem; however, during summer months when influent falls to 2 to 3 MGD, the plant is operating inefficiently in terms of power consumption as well as effluent quality. Infiltration and exfiltration from the system are likely causes of these large fluctuations. This study used methods designed to locate infiltration/ exfiltration problem areas and to determine those sewer mains requiring further study.

5.2 Compilation of Regulations on Environmental, Cultural, Safety and Land Use Issues.

Applicable laws and regulations generally are those that protect the environment, including controlling air and water quality and protecting plants and animals and their habitats; protect the human population from various life-threatening hazards; direct and encourage protection of historic buildings and sites; and control land use. While

Federal agencies are generally exempt from State and local requirements, environmental law contains many instances of State and local laws and regulations which respond to Federal requirements, instances in which State and local agencies administer, in essence, a Federal law. As a consequence, each of the multitude of laws, regulations, and ordinances listed in Chapter 5.0 must be examined individually, together with the details of a proposal or project, to determine applicability.

5.3 Resolution of Conflicting Recommendations

In recent years, a number of studies have been accomplished and recommendations made for reducing energy use and operating costs in the heating and cooling of buildings at Fort Lewis. Some of these recommendations conflict directly; an example is the proposal to upgrade the steam distribution systems and add a central heating plant monitor versus the proposal to convert from central steam/hot water to individual electric boilers. Reports involved are as follows:

a. Study of Electrical Heating Facilities at Fort Lewis, Washington. Contract No. DACA 05-77-C-0152. Valentine, Fisher and Tomlinson, Consulting Engineers, Seattle. January 1978.

b. Economic Analysis and Feasibility Report for Central Heating Plant Monitor, PN 359, FY-79 MCA, Fort Lewis, Washington. Contract No. DACA 05-77-C-0072. Boeing Engineering and Construction Division of The Boeing Company, Seattle, June 1977.

c. Feasibility Study for Conversion of Fort Lewis to All-Electric Heat. Contract No. DACA 05-76-C-0099. CH2M/Hill. October 1976.

d. Feasibility Study for Automation of Boiler Plants at Fort Lewis, Washington. Contract No. DACA 05-76-C-004. Wieland, Lindgren and Associates, Inc. November 1975.

Resolution of these conflicts is partly economic and partly in response to federal policy. Information available includes (1) data from the reports listed above; (2) Construction Criteria Manual, DOD 4270.1-M; (3) Army Facilities Energy Plan; (4) energy use and cost data developed in this study; and (5) data developed in the parallel Biomass Energy Plant Concept Study. The summary recommendations are as follows:

a. Retain and upgrade existing steam and hot water district heating systems

b. Reduce number of plants by consolidation and interconnection, and expand steam and hot-water distribution systems to connect all loads that are cost-effective to serve and to fully use plant capacities.

c. Add capability to fully and efficiently use the solid waste and wood fuel resources of Fort Lewis to reduce oil fuel consumption